DECONTAMINATION PROCEDURES AND RISKS TO HEALTH CARE PERSONNEL*

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VARIOUS radiation accidents, irradiation and external or internal contamination by radioactive material, require different medical responses. The level of urgency is much higher when dealing with contaminated patients. Paradoxically, a patient who may have received a potentially fatal dose from an external radiation source (located at some distance from his body) does not require emergency medical care, whereas external or internal radioactive contamination, which may not cause any effects for a long time, should be removed as soon as possible to avoid potentially harmful late effects from radionuclides deposited in certain areas.

HISTORICAL PERSPECTIVE

The frequency of serious contamination by radioactive material is exceedingly low.[1] In only a few accidents has significant external or internal contamination been a problem. Examples of such accidents are the Hanford accident[2] and the accidental depositing of radioactive fallout on the Marshallese Islanders, Japanese fishermen, and United States Navy personnel in 1954.[3,4]

However, minor incidents and radiation accidents in which low level contaminations occur are more frequent and can happen in spite of all precautions, guidelines, and safety regulations. This type of accident usually occurs in fixed facilities: isotope production facilities, industrial sites, medical and research laboratories, and other sites where radioactive

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materials are handled. And, occasionally, transportation accidents are complicated by the presence of radioactive material. Experience has shown that in most of the serious contamination accidents only a few people have been involved. With this historical fact in mind, I shall restrict my remarks to decontamination procedures to be applied when dealing with small numbers of patients (fewer than 10) rather than the decontamination options we have for large numbers of people.

DECONTAMINATION: STAFF, EQUIPMENT, AND SUPPLY REQUIREMENTS

The purpose of decontamination is threefold: first, to reduce the dose to the skin and to the rest of the body from an externally deposited contaminating source; second, to prevent or at least to reduce the uptake or incorporation of radioactive material into the body; and third, by proper decontamination procedures to confine the contamination to an area as small as possible and so to prevent spreading the contaminant on personnel, equipment, or throughout facilities.

Who should be authorized to decontaminate persons? If at all possible, trained nurses and physicians under supervision and with the assistance of health physics personnel should be in charge of decontaminating patients. However, in many instances, especially in fixed nuclear installations, a radiation worker will probably decontaminate himself, especially when no trauma is associated with the contamination. Most of the time the contamination is likely to be limited to small areas of the body, such as the hands, face, and occasionally the feet or legs. The necessity of having to deal with a patient whose entire body surface is contaminated is highly unlikely. If wounds are contaminated, medical assistance in the decontamination procedure is essential.

Fixed nuclear facilities with potentially serious contamination problems usually have a decontamination and first aid facility onsite. Most hospitals have no decontamination facilities. However, according to the guidelines of the Joint Commission of Accreditation of Hospitals, each hospital should be prepared and equipped to handle a contaminated patient. To meet this requirement, it is not necessary for a hospital to have a dedicated decontamination facility. It will suffice to have a designated area within the emergency room or any other practical area within the hospital to serve as the radiation emergency area; the requirement is that the contaminated patient be handled safely with little chance of spreading the contamination to other areas of the hospital. This facility should have essential life

TABLE I. ESSENTIAL DECONTAMINATION EQUIPMENT AND SUPPLIES

Protective clothing
Dosimeters for personnel
Radiation signs
Ropes
Geiger-Mueller survey meter
Floor covering/tape/sheets/blankets
Sample-taking kits
Plastic waste collectors
Decontamination agents

support systems, plenty of water, sinks, possibly a shower, and perhaps a commercially available decontamination tray with some sort of device to provide for collection of fluids. The tray is useful when a contaminated patient is unable to stand or sit.

Some of the equipment and supplies needed to handle a contaminated patient are: protective clothing (surgical gowns, masks, caps, boots, etc.), floor covering (cardboard or paper), large plastic lined trash cans, plastic carboys to collect decontamination fluid, sample-taking kits, and various supplies for decontamination as suggested in Table I. Essential for decontamination is an ample water supply, possibly through flexible hoses. Radiation detection equipment is also required. For a general hospital, an ordinary Geiger-Mueller counter with beta and gamma detection capability should suffice. In the unlikely event that monitoring for alpha contamination is necessary, assistance to manage this kind of situation would have to be requested. Other equipment needed are ropes and various radiation signs to control access to the decontamination area. A number of papers have been published and several symposia have been held on the subject of hospital preparedness and decontamination facilities, supplies, and procedures. Some of these useful sources of information are listed as references 6,7,8,9,10,11.

PRIORITIES IN HANDLING A CONTAMINATED AND INJURED PATIENT

Even in the presence of radioactive contamination, the medical team provides first aid and concentrates on life-saving measures before attempting to decontaminate. Medical treatment can begin as soon as the extent of the contamination is known and the radiation safety officer has determined that the potential radiation exposure of the medical staff is not excessive.

Only when the patient's medical condition is stabilized can we consider what to do about the contamination. Prior to decontamination, one must determine where the contamination is located and how much contamination there is. This is best done by surveying the entire body from top to toe using radiation detection equipment. Radiation levels should be recorded in an anatomical chart or another type of record for future reference. Based on the findings of the survey, swab samples should be taken from areas of high concentration for analysis in the nuclear medicine or other radioassay laboratory. In addition to these swab samples, it may be useful to take samples from both nares soon after exposure to radioactive material.

In any accident in which an uncontrolled release of radioactive material has occurred and a victim has sustained injury, such as wounds or burns, one must assume these wounds are contaminated until proved otherwise. As a general rule, wounds should be decontaminated before intact skin is decontaminated.

First, all clothing should be removed and the contaminated wound and surrounding area delimited by covering adjacent portions of the skin. Decontamination of wounds is performed by irrigating the wound with copious amounts of physiological saline or sterile water. If dealing with a severe laceration, irrigation with a steady stream of fluid or water-pic may more easily clean the wound. After irrigation, the wound should be covered by sterile dressings and the skin next to the wound decontaminated. After this final step of decontamination around the wound, the wound can be closed surgically.

If for some reason irrigation does not lead to satisfactory decontamination of a wound, surgical decontamination may be necessary. It should be emphasized, however, that the decision of surgical decontamination, which technically is nothing but debridement of the wound, should be made with the advice of expert consultants. If surgical decontamination seems to be required, the location of the contaminated wound and the expected final and functional outcome of the surgical procedure must be taken into consideration. Another consideration is the age of the patient as it might relate to the latency period for radiation-related malignant disease. In addition to wound decontamination by irrigation, surgery, or both, decorporation and chelation therapy are other means to decrease or to avoid incorporation of radionuclides, especially the transuranic elements.

Generally, burns are treated as any burn would be treated. The initial treatment of burns requiring irrigation for cleaning, spontaneous drainage from the wound, and eschar formation help to remove remaining contamination from a burn site.

Experience has shown that most contaminated wounds are small puncture wounds. If the contaminant is such highly radiotoxic substances as plutonium, americium, or californium, bleeding should be maintained by use of a venous tourniquet. Small puncture wounds of this sort, especially when contamined with particulate matter, are best treated simply by taking a skin biopsy using a skin-punch biopsy tool commonly used in dermatology. In removing the full thickness biopsy plug, the contaminating agent is usually also removed.

Decontamination of Skin, Hair, Eyes, and Ears

Decontamination of intact skin is somewhat simpler. Contaminated areas should be first delimited to protect uncontaminated areas of the skin. Some useful decontamination agents are listed in Table II. These are merely suggestions or guidelines with regard to the choice of various agents which one might consider to use and to keep on the shelf of a decontamination area. Generally, it is best to begin with a simple method such as lukewarm water and a surgical soap, Betadyne™ or Phisohex™. Gentle scrubbing of the skin with a soft hospital brush for three to four minutes followed by a thorough rinse (two to three minutes) using a continuous stream of water should be repeated three to four times before a more aggressive method is tried.

Between each decontamination step the skin should be dried and monitored using the Geiger-Mueller counter. If soap and water do not remove the radioactive material, an abrasive agent can be used, for instance, a mixture of 50% Tide™ and 50% cornmeal made into a paste. Again, gentle scrubbing for three to four minutes, followed by thorough rinsing and drying, should be used several times before trying a more aggressive method.

Instead of using the abrasive cornmeal-Tide™ mixture or a mild abrasive soap (Lava™), one could consider use of a household bleach in undiluted form for small contaminated areas and diluted 50:50 with water for decontamination of larger areas. One even more effective method is the application of 4% aqueous potassium permanganate, a technique only to be used by someone who has experience with potassium permanganate. To avoid damage to the skin, the stain must be removed within two minutes by using 4% aqueous sodium bisulfite. This decontamination is usually successful.

TABLE II. SUGGESTED AGENTS FOR DECONTAMINATION

1. Water and surgical soap
2. Mixture of 50% Tide and 50% cornmeal made into paste with water
3. Mild abrasive soap (Lava)
4. Clorox—undiluted for small areas, otherwise dilute (50/50)
5. Rinse or soak in stable isotope solution
6. Apply 4% potassium permanganate and remove stain with 4% sodium bisulfite

Decontamination should be as thorough as practicable; avoid irritation of the skin.

If the hair is contaminated, we recommended shampooing the hair two to three times. Each time shampooing should be followed by a thorough rinse with 3% citric acid. Only if several attempts using this technique have failed should one consider clipping the hair.

In case of contamination of the eyes, thorough irrigation is indicated. The rinsing stream should be directed to the outer canthus of the eyes to avoid the possibility of flushing any material into the lacrimal duct. Contamination of the ears is also treated by irrigation using a conventional ear syringe, provided that the tympanic membrane is intact.

In the unlikely event of whole body contamination, the entire body must be decontaminated. This is easily done by putting the patient in a shower if he can stand up. Otherwise, decontamination can be done on a decontamination tray. Showers should not be given if the contamination is limited to a small area of the body, because showering increases the chances of spreading contamination.

One question always raised in decontamination exercises or demonstrations is "At what point can one stop the decontamination?" From a practical point of view, one would say "stop decontamination when radioactive material can no longer be removed from the skin." In addition to this general rule, various agencies or groups have set skin contamination limits which are shown in Table III. According to the International Atomic Energy Agency, for instance, 0.05 mrad/hr from beta or gamma contamination detectable at the surface of the skin would be a level at which decontamination could be stopped. The Nuclear Regulatory Commission's and National Council on Radiation Protection's figure, 0.1 mrad/hr, is twice as high.

POTENTIAL RISK FOR MEDICAL DECONTAMINATION TEAMS

The potential risk for rescue workers and medical staff who have to

TABLE III. SKIN CONTAMINATION LIMITS

	α-Emitters		β and γ Emitters	
	Typical CPM[a]	*dpm/100 cm^2*[b]	*Typical CPM*[c]	*mrad/hr*[d]
NRC[e]	200 (~15%)	2220	250	0.1
ORNL[f]	14 (~15%)	150	750	0.3
REAC/TS[g]	14 (~15%)	150	25	0.01
IAEA[h]	100 (~15%)	1130	125	0.05
NCRP[i]	200 (~15%)	2220	250	0.1

[a] Typical counts per minute
[b] Disintegrations per minute per centimeters squared
[c] Typical counts per minute
[d] Millirads per hour
[e] Nuclear Regulatory Commission
[f] Oak Ridge National Laboratory
[g] Radiation Emergency Assistance Center Training Site
[h] International Atomic Energy Agency
[i] National Council on Radiation Protection and Measurements

handle a radioactively contaminated patient is twofold. The contaminated patient is a radiation source that could conceivably be a risk in terms of external irradiation of the whole body, and there is a risk of contamination in handling such contaminated patients.

To avoid contamination, it is generally recommended to wear protective clothing. Usually surgical dressout—possibly two gowns instead of one, two pairs of gloves, ordinary surgical face mask and cap, as well as boots—is adequate. This clothing does not protect against penetrating gamma radiation or x rays, but it does protect against contamination.

How large is the risk in handling an actual case? Historically, in all accidents involving radioactive materials, there has never been a serious risk to rescue or medical staff. An example at the lower end of the scale is the Millstone incident (December 13, 1977), in which one man sustained multiple superficial abrasions on both legs contaminated with fission products. Eight people on the medical staff were involved in the decontamination procedure, and the highest dose received by anyone on the medical team was 13 and 14 mrem.[13] The readings for the other staff members were 3, 0, 4, 1, and 1 mrem—very low exposures considering that a technically good chest x ray gives a dose of approximately 10 to 20 mrem.

At the other end of the scale is an accident at the Idaho Falls (SL1, 1945) reactor in which the three people involved were killed by the explosion. They were also heavily contaminated, and the problem for the

TABLE IV. GAMMA RAY EXPOSURE RATES FROM ONE CURIE SOURCES*

	At contact R/min	At 1 meter R/min
Cesium-137	513	0.33
Cobalt-60	2,075	1.30
Iridium-192	813	0.48
Radium-226	1,310	0.825

*Modified from Tables 3 and 6 of NCRP Report No. 40.

rescue team and the medical autopsy team was to remove the contaminated bodies from the heavily contaminated reactor facility and to handle the contaminated bodies during the autopsies. The contamination was so heavy that the meter readings were up to the range of 300-400 R/hr for certain portions of the bodies. In spite of these high radiation levels, the maximum dose sustained by anyone on the rescue team was 27 rem and the maximum dose for the pathology team was 3,680 mrem. It is believed that the high dose of 27,000 mrem to two of the rescue team members was not only due to exposure from the contamination present in the area and on the bodies, but was also due to radiation from the reactor that during the rescue operation became critical one more time. If it had not been for the second criticality in the reactor, the radiation dose for the rescue team would probably have been much lower.

In considering the extreme situations exemplified by these two accidents, it is fairly safe to assume that a properly trained medical decontamination team can handle almost any serious accident complicated by radioactive contamination. Further to illustrate the validity of this assumption, I would point out, as shown in Table IV, that considerable amounts of contamination can be handled relatively safely based on two fairly elementary principles of radiation protection—distance and speed. As presented in the table, one curie quantities of ^{137}Cs, ^{60}Co, ^{192}Ir, or ^{226}Ra have exposure rates of only 0.33 rem, 1.3 rem, 0.48 rem, and 0.825 rem per hour, respectively, at a distance of one meter. To put this into perspective, the astronauts of Appollo X received 0.480 rem and the yearly occupational exposure limits in the United States are 5 rem. Also, the dose limiting recommendation by the National Council for Radiation Protection is 100 rem for life-saving and 25 rem for less urgent radiation emergency situations (Table V).

These are reasonable limits, probably acceptable in terms of risk for

TABLE V. DOSE LIMITING RECOMMENDATIONS*

Emergency dose limits—life saving	
Individual (older than 45 if possible)	100 rem
Hands and forearms	200 rem, additional (300 rem, total)
Emergency dose limits—less urgent	
Individual	25 rem
Hands and forearms	100 rem, total

*From Table 2, NCRP Report No. 40

medical or rescue teams responsible for radiation accident management. One should remember that the radiation doses received in even extreme situations, such as the SL1 accident, and the doses acceptable to the National Council on Radiation Protection for life-saving measures are significantly below the clinical level of the acute radiation syndrome. This is quite different from the situation of a fire fighter who literally risks his life when rushing to the third floor of a burning house to rescue a child.

In summary, a radioactively contaminated patient can be safely treated in a general hospital provided that the medical staff is trained to handle this kind of problem and provided that a minimum of equipment and essential supplies are available.

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